Toward a Better Understanding of Ocean-Wave-Typhoon Interactions in the Western Pacific Ocean

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LONG-TERM GOALS

This project investigates the interplay among typhoon-strength winds, ocean surface waves and upper-ocean circulation during and after typhoon passages over the western Pacific Ocean and around the island of Taiwan.

OBJECTIVES

We use three numerical models and calibrate them against continuous measurements of ocean currents, temperature, wave heights and turbulence intensities from several open ocean moorings in the western Pacific. Through these calibrations, we will learn how to better represent winds, ocean currents and waves under typhoon-strength wind conditions in the western Pacific Ocean.

APPROACH

For the atmosphere, we use the Navy's operational West Pacific atmospheric model (COAMPS) and JPL wind to drive ocean waves and upper ocean circulation. For ocean waves, we use SWAN (Booji et al.,1999; Ris et al., 1999) to generate them and calibrate simulated results against observed wave heights from moorings. For the ocean circulation, we invoke the Naval Research Laboratory's East Asian Seas Nowcast/Forecast System (EASNFS, Ko et al., 2008) to simulate upper-ocean response. Resolutions of these models are sufficiently high. Mooring observations maintained by Taiwanese colleagues were from 3 subsurface moorings that measured upper ocean (top 500 m) currents and 4 ATLAS-like moorings that measured upper ocean temperature. Subsurface moorings are at stations SA1 (127.53°E, 20.37°N), SA2 (123.27°E, 21.23°N) and SA3 (123.63°E, 22.00°N). Four ATLAS-like moorings are at stations A1 (127.64°E, 20.34°N), A2 (123.25°E, 21.07°N), A3 (126.03°E, 18.52°N) and A4 (123.84°E, 22.13°N). Through calibration and analysis of the three models and observations, we intend to identify crucial oceanic and wave processes that regulate typhoon's strength and path.

Key individuals participating in this work include Shenn-Yu Chao as the lead PI and Dong-Shan Ko of NRL, who will maintain EASNFS and provide wind products. Ya-Ting Chang, visiting on as-needed basis from Institute of Oceanography, National Taiwan University, serves as the liaison between our modeling components and Taiwanese observation components. Her efforts along this line of investigation will constitute the bulk of her Ph.D. dissertation.

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WORK COMPLETED

From August to October in 2010 is the first intensive observation period (IOP), led by a command center in Naval Research Laboratory at Monterey, California. Ya-Ting Chang has stayed in Monterey during a good portion of IOP. We have backtracked all available typhoons around the IOP, and checked their influence on the observed upper ocean response, and predictability by EASNFS and SWAN. Results are mixed, but more positive than negative. Essential preliminary findings are summarized below.

RESULTS

(1) In August 2009, a westward moving category-1 typhoon (Morakot) landed on Taiwan on the 8th. The nearest temperature at the mooring site, 150 km south of the Morakot's track, showed highly baroclinic response. When Morakot skirted by, instead of monotonous cooling throughout the upper ocean, temperature around 350 m first rose by about 1℃ and then decreased by 4 ℃ to its lowest value in about one inertial period (36 hours). Since Morakot is about one year before the ITOP's IOP, details will not be given herein. Nevertheless, the baroclinic ocean response to Morakot in relation to the Kuroshio, thermal response around Taiwan, preceding tropical storm Goni and the performance of EASNFS is still under investigation.

(2) The internal tide emanating from the Luzon Strait is a prominent feature in the western Pacific (Figure 1). How typhoons modify it is another concern. Before we examine possible typhoon modifications, we first need to assess of the skill of NRL's EASNFS to capture the internal tides in the western Pacific. Our results are mixed but more positive than negative. In particular, using data from mooring station A2 as a reference, the EASNFS is able to capture the semidiunal internal tides reasonably well. At the diurnal frequency, the EASNFS is also able to reproduce the internal tides most of the time. In brief periods of relatively quiescent diurnal internal tides, however, the EASNFS tends to underestimate their intensity. The source of the discrepancy is still under our investigation.

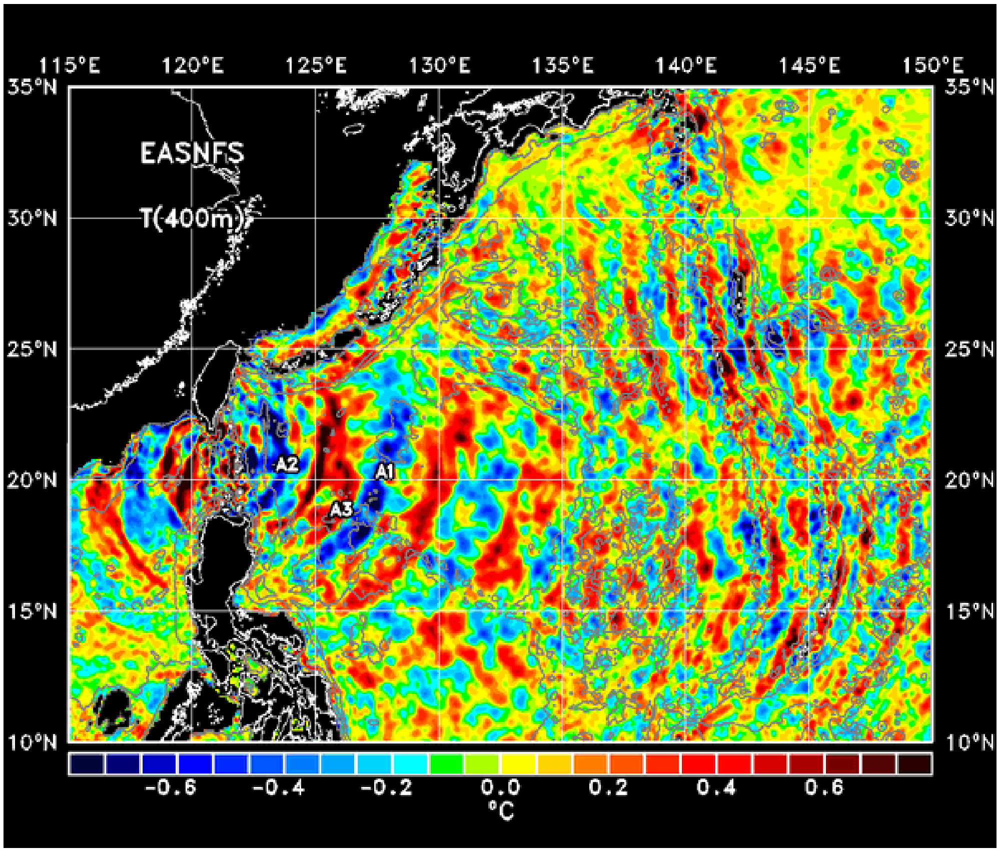

Figure 1 ITOP-10 internal tide prediction from EASNFS and mooring stations A1, A2 and A3

(3) The skill level of the wave model (SWAN) to reproduce (or predict) surface gravity waves and the performance of wave measuring instruments under hurricane strength winds are also of concern. With observed wave data and availability of wind products and upper ocean currents derived from EASNFS, ITOP offers an unique opportunity for us to assess the skill level of SWAN to address these issues in the western Pacific. Our assessment to date is mixed but still more positive than negative. When forced by the COAMPS winds and EASNFS-produced ocean currents, the SWAN model was able to reproduce significant wave height rather well. However, the modeled significant wave period is frequently lower than the measured significant wave period by 2~4 seconds (Figure 2). The discrepancy may come from many sources. First of all, the temporal resolution of input winds and ocean currents is 3 hours, which may (or may not) reduce SWAN's ability to simulate high frequency wave events. Second, wave measurements (in the present case, from directional wave package of TRIAXYS wave sensor clamped on mooring A4) often has problem to catch long waves (swells) correctly. Third, SWAN does not take the vertical shear of upper ocean currents into consideration; this may also result in underestimating the wave period. Fourth, for practical reasons, we reinitiate SWAN every 3 days rather than running it continuously; this may underpredict swells. We intend to track down these possible sources of discrepancies next year.

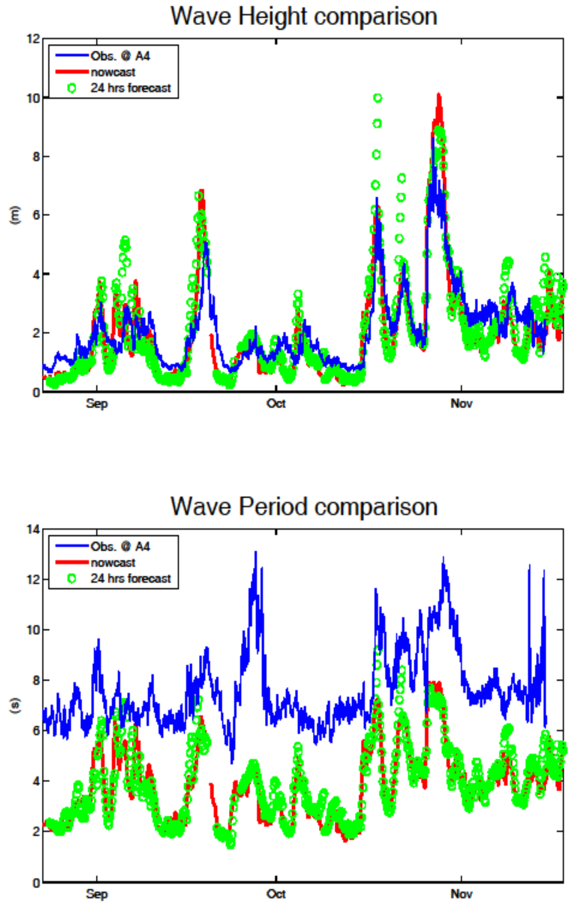

Figure 2 Observed, nowcasted and 24-hour forecasted ITOP-10 wave height and wave period at station A4 (123.84°E, 22.13°N)

IMPACT/APPLICATIONS

Under typhoon strength winds, the interplay among winds, upper ocean currents and surface gravity wave fields is quite complex. To a certain extent, the wave field alters the ocean mixed layer, which in turn regulates the amount of upper ocean heat content released to the atmosphere. Thus, a more realistic wave field may ultimately produce better typhoon strength and track forecasts. In this light, it seems necessary to include the upper ocean currents in order to better forecast typhoons after they come into contact with the Kuroshio and its adjacent eddies. Further, a more realistic wave field may also improve upper ocean circulation and lead to better regional ocean models. Taking advantage results from IOP-2010, our investigation along this line will hopefully advance rapidly.

RELATED PROJECTS

None in this year.

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